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VOL. XI LANCASTER, PA., FEBRUARY, 1921 NO. 6

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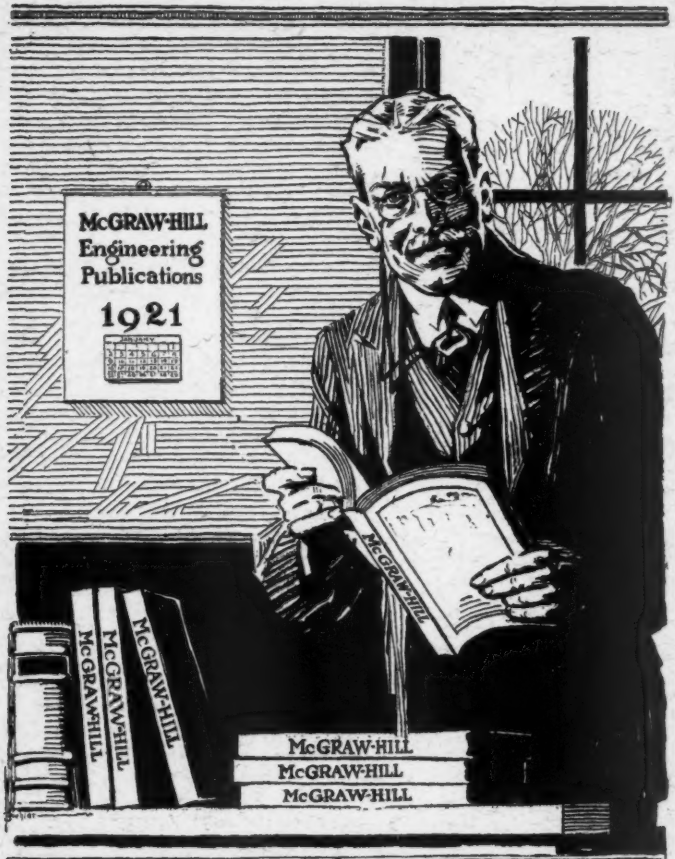

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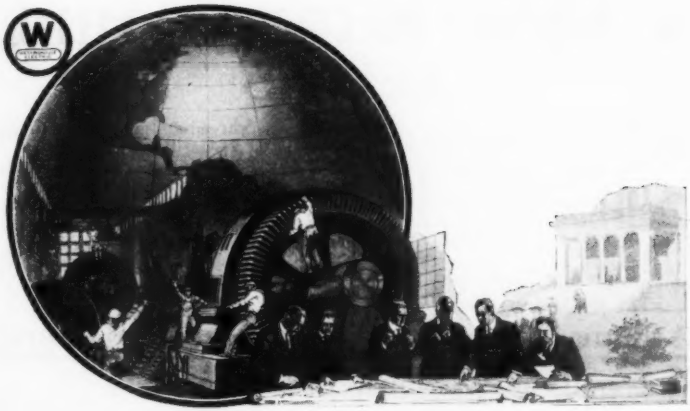

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THE SCARCITY OF THE COLLEGE-TRAINED ENGINEER IN PRODUCTION.

BY JOHN AIREY,

Professor of Engineering Mechanics, University of Michigan.

In "A Study of Engineering Education" by C. R. Mann, the statement is made that less than five per cent. of the production managers of the country are college trained. This percentage, doubtlessly, would have been even smaller if production executives of lower rank than manager had been included. In contrast to this, the percentages given by Dr. Mann for technical departments in various lines of industry average over fifty.

Few men familiar with factory organizations would dispute the above statements or even express surprise at the anomalous situation which they indicate. The writer believes that this inequality in the distribution of our engineering graduates is one of the most important questions in engineering education at the present time and proposes to present the case as he sees it.

National economy calls for the production executive to receive higher education in addition to the purely technical man. Higher education builds up a national asset in the highly educated few. Because of this it is financed largely by collective effort although under one per cent. directly participate in the benefits.

Because higher education is available only for the few it follows that it must be directed into those fields where it produces the greatest results.

What, then, is the criterion whereby one can determine whether it is justifiable for the State to subsidize higher education for a given field?

Admittedly, the commercial value of an individual, for any type of position, would be improved by four years' training.

For any given type of position the average salary paid is a measure of the difficulty of obtaining men. Further, if abnormal periods are ruled out when the supply or demand has suffered a sudden change, the average salary forms the best measure of the ability called for and responsibility carried.

Applying this principle, production work is at least as important as technical work. Why, then, should fifty per cent. of men engaged in the latter have State subsidized brains and only five per cent. of those engaged in the former activity? This is an inefficient expenditure of State funds, and the responsibility for the necessary changes lies squarely up to engineering educators.

For convenience this problem may be presented under the following heads:

1. The development of production in commerce.
2. The development of engineering education and the reasons for the exclusion of the production field.
3. Present endeavors to meet the situation.
4. Suggested policy.

The development of production on a large scale, frequently known as quantity-production, eventually caused the segregation in factory organization of production proper. This segregation has been largely responsible for the tendency of engineering graduates to go almost exclusively into the purely technical departments.

Quantity production is largely a development of the present century. Textile machinery, sewing machines and bicycles were among the earlier commodities to be made at reduced costs because of this principle. The automobile has been the real factor, however, which has accelerated this development—a development to which there is, seemingly, no finality. In earlier days "engineering" included the designing, making and marketing of the finished product. This is still largely

true where gross repetition in manufacture does not exist. Where quantity production is in operation, however the activities classed as "engineering" cover only the designing of the finished product, for, in the majority of cases, the design, even, of all auxiliary equipment is done outside of the "engineering" department. This is often a bigger design problem than the design of the commodity itself. The making of the extra equipment including jigs, fixtures and gages, and the operating of the plant, are now always outside the so-called engineering activities.

The definiteness of this cleavage of activities is appreciated by very few engineering educators. The extent to which production has emerged from engineering and has created a field of its own is greater in the United States than anywhere else. The cleavage is just as apparent if the staff be analyzed, as was shown in the opening paragraph of this article.

So definitely has production drifted away psychologically from engineering that the newly graduated engineer considers it *infra dig* to go into crude production. He fears to be deprived of scope for his highly technical training. Some graduates change their viewpoint a few years later—but in the meantime valuable time is lost.

The development of quantity production is materially retarded because of this sidetracking of men to the more technical fields of design, who, because of their higher training, could give an impetus to its progress which is difficult to estimate.

Engineering education itself is to blame for the shortage of college-trained engineers in production. The development of engineering education is recent and is at present undergoing decided changes.

A century ago university work was almost wholly non-utilitarian—knowledge for the sake of knowledge. At this time engineering began its rise from a handicraft to a science. The last century was rich in the development of pure science. Science was eagerly harnessed by engineers and engineering often provided the incentive and financial backing for further

developments in pure science. The value of science to engineering caused technical schools to develop—very elementary and narrow at first—until the relation of the time-honored universities to this new type of educational institution was obviously a problem pressing for solution.

The solution was naturally amalgamation. The universities had to extend their activities to applied science. The opposition on the part of the older universities, proud of their classical atmosphere, to such sacrilege as applied science is well known. This opposition has been substantially everywhere overcome, but more distinctly so in the United States.

At first the instruction given for an engineering degree was very fundamental. As the major subdivisions of engineering took form, however, the new education briskly fell into line, subdividing itself and degrees are now awarded in civil engineering, mechanical engineering, electrical engineering, etc. This century has seen the recognition by educational institutions of from six to ten further subdivisions in each of the above general fields.

The first group of subdivisions was a desirable development. The further subdivision was a movement that swung too far. The weight of opinion among educators is that specialization has more than had its day. The colleges, apparently anxious to make up for the lack of coöperation of the past, have, on the slightest encouragement, instituted new specialties, thus tending more and more to turn out narrow technicians rather than engineers.

This drive in the direction of specialization has had excellent good will behind it, a real desire to do the most good to the commercial world of engineering. Those who cavil at this statement are reminded that the *raison d'être* of engineering training in our universities is *commercial advantage* with a quarter of a century looking ahead policy.

The writer believes that it is just this insistent well meant tendency to specialize that has brought about the present condition in production. The attitude of mind fostered by look-

ing along specialized technical lines is just the attitude that would diagnose production, incorrectly, as essentially the function of the uneducated shopman. In consequence, the responsible positions in production are filled by the survival of the fittest with the handicap of a meager education.

Present endeavors to meet the situation have not succeeded in developing the required viewpoint among newly graduated engineers. It will be argued that specialization along the line of "Industrial Engineering" or "Industrial Management" or "Scientific Management" or the more general caption "Efficiency Engineering" is a movement to fill the gap under discussion. This is partially true, but it is not succeeding, as shown by the statement already quoted, that college-trained men constitute under five per cent. of all production managers. This movement is handicapped by being regarded as an outgrowth of mechanical engineering. Although historically it *is* such an outgrowth, still in actual practice the drift away from mechanical engineering is far too pronounced for the two to be considered closely allied.

As it is now being developed, Efficiency Engineering, etc., suggests too distinctly aiming exclusively at fitting men for the highest positions. The word "management" appears with such insistence in discussions and writings connected with this development, that many men look askance in the belief that it is an attempted incubator for company presidents.

Further, to discuss the psychology of this movement, there is a distinct strain of thought engendered which pictures industrial organizations as similar to the Army in which we have two classes: men of the higher type serve their apprenticeship in higher strata and never know the ranks except from an altitude.

The writer believes that here lies the chief trouble with this development because industrial organization is a growth entirely different from that of an army, much more loosely held together and with very different discipline.

If the inequality in the distribution of our engineering

graduates in the production and in the purely technical fields is to be corrected, it is apparent that the viewpoint of our students must be so changed that they will see the real scope of production. This can only be accomplished by so changing the present system of training as to lay the emphasis in a new way on production and on production problems.

It is difficult for one to appreciate the problems of production after being trained to an apotheosis of technical matters. The attitude of mind needed for the field of production is a blending of that attitude developed by a study of economics and of that developed by a study of technical subjects. The combination should be given a preponderance on the economic side rather than on the technical side. A strain of the legal mind is also needed. A department of economics in the College of Liberal Arts could quite logically undertake to train students for this field. In the writer's opinion, however, the College of Engineering is the best equipped to undertake this task.

In spite of production being an outgrowth of mechanical engineering the training of the two must now be separate. There is a decidedly bigger gap between the instruction called for and the present instruction given to mechanical engineers than there is between that given to mechanical and civil, or mechanical and electrical engineers. Because of this a new department should be established, known as "Manufacturing Engineering" or "Production Engineering."

The curriculum should include no specialized professional engineering courses. More English should be required and less mathematics and less mechanics. More emphasis should be placed on economics, including sociology, with the particular reference to employment and welfare matters, on law, with its extension to the idea of authority radiation and correlation, and on statistical analysis, psychology and accounting. The usual foreign language requirements should be retained. On the more technical side, in addition to the fundamental subjects already referred to, geometry, Sketching of Machine

Parts, Drawing and Machine Design should be given. Under Design, jigs, fixtures and gages should preponderate.

A very thorough study of the organization of a factory for the production of some one article should be made. Such a study should embrace planning, decisions on purchased parts, setting of piece rates and probable cost of production. This article should not be so complex as to bewilder the imagination of the student.

In the college shop some articles of a more pronounced simplicity should be made in quantities. This must be simple enough to enable it to be actually put into *production* and a *continuous stream* produced. Failing this, economic experience is forfeited, leaving only the technique which is already overstressed.

Considering the incessant cry throughout the country for production, coupled with the fact that we are developing the production system, more and more, in the commercial world, it would appear to be the plain duty of our institutions of higher education to turn a stream of graduates in this direction as rapidly as possible. If this were done with the same vigor as for the technical branches, it would be difficult to estimate its value, in the next decade, to the nation as a whole.

In industry there is no such definite plane of cleavage as in the Army and this point of view must be given to the student, so that he will be willing to start as an operator. His superior mental development will enable him to move ahead of his fellows. This opens up to the graduate a broader avenue of advancement with a greater probability of reaching the top rung of the ladder than there is in the so-called "engineering" departments.

Only a favored few would finally reach high altitudes and the others would remain at various levels. The mediocre student who sits before a drafting board ten to fifteen years after graduation or performs chiefly routine functions in a laboratory, would find his level as a sub-foreman in a small department. His income would probably be somewhat higher

though his collar might not be so clean. Surely it is not beyond the power of the university so to control its atmosphere as to make this objection a factor of small consequence.

Consider that portion of our student body who obtain but slight benefits from higher education due to their intellectual limitations, and who would reach possibly no higher than sub-foremen. As these men would be closely in contact with the rank and file, the maximum opportunity would be offered for the spread of a more liberal atmosphere, some of which they must have absorbed in their association with the university.

Just as the non-com. is the backbone of the Army, so the foreman is the backbone of a factory—the last link between the management and the men. If a stream of college trained men spent a transitory period as foremen in the factory instead of in pseudo-gentility in an office or laboratory, often occupied with inferior work, what a wholesome sociological influence this leavening would have on the rank and file of industry, and per contra on themselves. It is an interesting reflection.

FROM THE NOTEBOOK OF AN ENGINEER. I.

BY R. FLEMING,

American Bridge Co., New York City.

The writer has often wished that he was a college professor, not that he would write a textbook but that he would have more time to spend with those already written. All textbooks, even poor ones, reflect the individuality of the author or compiler. Phases of a subject that are emphasized in one book are passed by in another. If an author has conceived anything original he will be sure to give it a prominent place in his book. It is these things that make it a delight to browse in a desultory way among a score of textbooks or to become acquainted with a new one. Such a course may be of doubtful benefit to a student in college but to one who has passed his college days and still remains a student it presents comparisons, offers new methods and widens the mental vision.

Some notes from excursions into the realm of textbooks and the domain of college professors will be given in this article.

Five books will be cited to show what is meant by individuality in a book.

Goodman's "Mechanics Applied to Engineering" is a British book that has met with a favorable reception in the United States, "a matter of agreeable surprise" the author states in the preface to one of his later editions. One reason for its success is that the book is well adapted to the occasional reader. A chapter on Gyroscopic Action and new matter on the Strength of Flat Plates, Deflection of Beams due to Shear and kindred subjects are among the additions found in the 850 pages of the last edition. A unique feature of the book is the "modulus figures" of a great variety of sections. A "modulus figure" has been defined: "The shaded portion of

Fig. — represents a portion of the area of a section on which, if a uniform stress be applied equal to the unit stress in the outer fibers, the total stress and the moment with respect to the neutral axis will be the same as that of the actual distribution. This is called the *stress-distribution diagram*, or modulus figure." Boyd.

Morley's "Strength of Materials" is another British book favorably known in the United States. Unlike Goodman, who uses the calculus sparingly, Morley makes more use of it than the occasional reader will care to follow. But his results are easily interpreted. For instance, under the heading "Tension in a Plate Perforated by a Single Circular Hole," it is easy to understand: "the circumferential tension is *three times* the uniform tension in the plate at points remote from the hole," even if the steps that lead up to this statement require considerable study to be mastered. A chapter of 33 pages is given to Built-in and Continuous Beams, another of 46 pages to Bending of Curved Bars and another of 23 pages to Flat Plates. The book deserves a place in the library of every teacher of structural engineering. If accessible to the student, parts of it can well be assigned for collateral reading or study.

Boyd's "Strength of Materials," in the determination of the Deflection of Beams with Two Supports, has 19 pages given to the conventional method of analysis by double integration—the only method known previous to 1868—followed by 16 pages of the deflection of the same beams determined by the method of area moments. An illustration of how a single sentence may throw light upon a difficult subject will be taken from Professor Boyd's book: "The product of inertia has no physical significance but is a convenient tool in finding the moment of inertia of a plane area with respect to any axis, as will be seen in the article which follows."

Slocum's "Resistance of Materials" under "Euler's theory of long columns" deduces the column formula for hinged ends in an unusual way. The elastic curve is assumed to be a parabola instead of a sinusoid. The moment diagram is also

assumed to be a parabola, the center ordinate of which is equal to the column load P, multiplied by the deflection d or Pd. The area A of one half the parabola equals

$$2/3 \times Pd \times l/2 = \frac{Pdl}{3},$$

l being equal to the length of the column. The distance x from center of gravity of parabola to end equals $5/8 \times l/2 = 5/16\, l$. From the general deflection formula and with the beam loaded with the bending moment parabola

$$d = \frac{1}{EI} Ax = \frac{1}{EI}\left(\frac{Pld}{3}\right)\frac{5l}{16} = \frac{5}{48} \cdot \frac{Pl^2d}{EI},$$

from which

$$P = \frac{9.6EI}{l^2}.$$

If the elastic curve had been assumed to be a sinusoid instead of a parabola, the result would have been the well-known equation,

$$P = \left(\frac{\pi}{l}\right)^2 EI = \frac{9.87EI}{l^2}.$$

Woodward's "Rational and Applied Mechanics" is a book that reflects in an unusual degree the personality of the author. It could appropriately be entitled, "Calvin M. Woodward, his Notebook," so often does the author draw upon his experience as a teacher and problems found within the observation of his students. The Preface begins: "This book is written primarily for students entering upon their second collegiate year," and ends: "Finally, it is hoped that no teacher will attempt to rush a class of undergraduates through the book in forty weeks."

The range of subjects covered is wider than usually taught under Mechanics. One chapter is entitled "Elementary Graphical Statics" and another "The Efficiency of Compressed Air." Probably few teachers would adopt the book as a text book, but that no real teacher could fail to find in it

valuable suggestions in presenting work to his students is evidenced by the page headings and titles of many of the articles. Taken almost at random are found headings and titles as, The generation of various spirals; The length of a sidereal day; Which dominates, strength or stiffness; Solution by the 'Doctrine of Least Work'; Solution by 'Displacements'; 'Looping the Loop'; The 'Thrust Block' of the U. S. Battleship Delaware; The difference between momentum and energy; The motion of trains; The economy of hollow shafting and other subjects to which scant allusion is made in most textbooks.

The present writer once received from an engineer who was sojourning in the Southern pine country a "hand-colored post card" showing one of the long leaf pines of that region. In the space for messages the engineer had written, "How do you suppose they stand that high without proper wind bracing?" His question is answered on page 405 of Professor Woodward's book:

Nature builds cantilevers of "uniform strength" in the shape of tapering trunks of trees, which are solid, and in bamboo poles and wheat straws which are hollow. The wind blows from any horizontal direction, so the cross-sections are circles or rings, of varying radii. If, like a palm or a tall southern pine, the load is concentrated (that is, if the foliage which catches the wind is bunched) at the top, it is a cantilever with a load at the end. If W is the total force of the *wind* (in lbs.) and h the distance from the ground to the center of wind pressure, the bending at any height is $M = W(h - z)$. The value of I for a radius x is $I_x = \pi x^4/4$ and a is p_1/x.

Hence

$$M = aI = \frac{p_1 \pi x^3}{4} = W(h - z)$$

and

$$x^3 = \frac{4W(h - z)}{\pi p_1},$$

which is the equation of a cubic parabola with the vertex at the top of the tree.

Hence the effective radius at the base is $R = \sqrt{4Wh/p_1\pi}$ in which p_1 is the fiber stress just under the bark, on the assumption that the internal stress varies uniformly (that is, that E is constant for all radii). So much for the ideal tree. Actual measurements show a fair approximation on the part of real trees to the ideal form of a cubic-paraboloid of revolution.

If the tree stands alone on the level plane, it is more often shrouded with a foliage nearly to the ground, so that it approximates a cantilever with a uniform load, and the trunk tapers more rapidly, in accord with theory, which is, that it approaches a common parabola in outline.

$$x^2 = \sqrt{\frac{2W}{\pi f}}\,(h - z).$$

In the case of a growing bamboo, we see an economic cantilever of "uniform strength" in the shape of a conoidal tube.

A professor might take a lesson from the story told in a foot-note of a young candidate for honors who to the question: "What makes a trolley-car continue moving after the current is shut off?" answered: "It is the *force* of the *power* of the *momentum* of the *energy* of the car." "Evidently he had no exact knowledge of any one of the four important words he used; so he put them all in."

An engineer some years out of college on taking up a textbook often finds that he does not possess the requisite knowledge of the subjects that precede. The only remedy is to supply that knowedge by going back and back until he finds himself on solid ground and starting from that point. To understand an equation in the calculus he may have to turn to negative exponents in elementary algebra. In mechanics he may have to hunt up arithmetical or geometrical progression in an arithmetic and in any engineering study he can make but litle progress unless he is well-grounded in trigonometry. An engineer who had been wrestling for years with the inadequate knowledge obtained from a poor college course in mechanics, decided to overcome his handicap by systematic study. To his surprise he found the college textbooks beyond

him. He finally took up Merriman's "Elements of Mechanics: Forty Lessons for Beginners in Engineering." By reading every page and solving every example he experienced the truth of the author's statement near the close of the book. "The student who solves the four hundred problems here given will have constructed a broad and strong foundation for his future studies in theoretical and applied mechanics." Is not Professor Merriman also correct in his views?: "In the opinion of the author there should be given in every engineering college two courses in rational mechanics, an elementary one during the freshman year in which only as much mathematics is employed as is indispensably necessary, and an advanced one after the completion of the course in calculus."

A textbook while adapted to the classroom may be disappointing as a book of reference. One professor says that a book cannot be written that will be equally valuable to a student and a practising engineer. He is somewhat mistaken. A textbook should contain more than is actually taught in the college course. The student should not be led to think that he has exhausted a subject when he has finished the textbook. It goes without saying that the books a student uses in college are those that he will turn to in after years for help in time of need. As Professor DuBois wrote forty years ago: "It is surely, then, no objection that such books should give a complete view of the whole ground, rather than a short and meager presentation, which can have but a transitory value in merely introducing the student to the subject, and which often lead him to suppose that there is but little more of it worth knowing." Some excellent American textbooks could profitably be made longer. The distinctive material for the college course could in some way be indicated.

A great asset to a textbook is plenty of numerical examples, especially if they are problems such as an engineer meets in profesional life. Many of the later textbooks, more particularly those in Mechanics and Strength of Materials are giving such problems in abundance. Morley says in the Preface of

his book previously noted: "Many fully worked out numerical examples have been given, and the reader is advised to read all of these, and to work out for himself the examples given at the ends of the chapters, as being a great help to obtaining a sound and useful knowledge of the subject."

Contrary to Morley's practice and views are those of Woodward as given in the Preface of his book previously noted: "The Author has not cared to multiply problems. To go beyond clear illustrations of general principles and useful methods of analysis, is to waste time and opportunity. To ring endless changes upon bodies falling in a vacuum, and projectiles flying through empty space, is to kill time and 'keep students busy.'" It is not necessary for the student to work out all the problems of a large collection. Merely reading them is educational. Having the answer to a problem, given either after the problem or in the appendix, is a great help to the student outside of college walls. It is doubtful if much is gained by withholding answers from college students. The writer was told by a professor that in his institution solutions to the problems in the textbooks used could be found in the various fraternity houses, being handed down from one generation of students to another.

Nothing detracts from the working value of a book so much as errors, typographical and otherwise. An example may have the decimal point in the answer misplaced, an equation may have the $\times$ sign where the $+$ sign is intended or there may be downright errors in the text itself.

"I like to have errors in the textbook," said one professor. I come before the class and this colloquy ensues:

"'Gentlemen, have you gone carefully over the lesson?'

"Silence gives consent.

"'Did any of you have any trouble with it?'

"Usually another silence.

"'Well, did you all verify Equation (blank)?'"

Equation (blank) is an error, and the professor has them trapped. This may be fine for a class; it encourages thought

and shatters a belief in the infallibility of textbooks. But the practising engineer seldom has time to verify equations. He wants to take them as they are written. However, this is with some books an unsafe practice, especially with the first edition.

A clearing house for information regarding technical articles written by professors and published in the periodicals of their respective colleges is a thing to be desired. A professor often gives time and thought to elaborating a subject in which he is particularly interested and presents the results of his studies in the college periodical. A few cases will be cited (the list could be made much longer):

Professor Greene—"Bolts, Bars, Plates and Plating for Stacks," *The Polytechnic*, Vol. 30, April 27, 1914.

Professor Jacoby—"A Review of Recent Advances in the Length of Spans of Different Classes of Bridges," *The Cornell Civil Engineer*, Vol. 28, Nov., 1919.

Professor Kommers—"Graphical Determination of Beam Deflections," *The Wisconsin Engineer*, Vol. 22, Nov., 1917.

Professor Maney—"Secondary Stresses and Other Problems in Rigid Frames," *The Minnesota Engineer*, Vol. 23, May, 1915.

Professors Patterson and Stevens—"Shear and Bending," *Michigan Technic*, Vol. 28, May, 1915.

Professor Roys—"General Theory of Plane Motion, Rotation and Translation," *The Journal of the Worcester Polytechnic Institute*, Vol. 21, Nov., 1917.

Professor Thomas—"The Lateral Resistance of Metal Bolts and Lag Screws in Wood," *The Rose Technic*, Vol. 26, Oct., 1916.

Professor Wilson—"Wind Stresses in the Steel Frames of Office Buildings," *The Technograph*. Vol. 28, Jan., 1914.

Professor Wolf—"Molybdenum," *Colorado School of Mines Magazine*, Vol. 8, May, 1918.

The writer has searched fully a hundred textbooks for certain information regarding "Napierian," "natural" or "hyperbolic" logarithms. How they differ from the common

logarithms, how one system can be changed to the other, how they are determined, are all explaned. But just what did Napier discover or invent? How did he derive *his* logarithms? Whether "higher arithmetic," "university algebra" or advanced calculus were examined—they all failed to give Napier's line of thought or his methods. (It should be remembered that Napier gave his wonderful invention to the world in 1614—before Sir Isaac Newton was born and sixty or seventy years before the birth of the calculus.) It was only when the writer came across Cajori's "History of Elementary Mathematics" that his queries were answered. The information contained in the sentences quoted from this excellent book will be new to many readers:

"His logarithms were the result of prolonged, unassisted and isolated speculation. . . . In the time of Napier our exponential system was not yet in vogue. . . . That logarithms flow naturally from the exponential system was not discovered until much later by Euler. . . . Napier calculated the logarithms, not of successive integral numbers, from 1 upwards, but of *sines*. His aim was to simplify trigonometric calculations. . . . It is evident from what has been said that the logarithms of Napier are not the same as the natural logarithms to the base $e = 2.718$. This difference must be emphasized, because it is not uncommon for textbooks on algebra to state that the natural logarithms were invented by Napier. . . . It must be remembered that Napier did not determine the base to his system of logarithms. The notion of a 'base,' in fact never suggested itself to him. The one demanded by his reasoning is the reciprocal of that of the natural system." Further along in the same book we read, "In the study of quadratures Gregory St. Vincent found the grand property of the equilateral hyperbola which connected the hyperbolic space between the asymptotes with the natural logarithms, and led to these logarithms being called 'hyperbolic.'"

Regarding the nomenclature, Napierian or natural, it may be interesting to note that Webster's International Diction-

ary under "logarithm" mentions Napierian logarithms, "which are often confounded with natural logarithms with which they are connected by the relation,

$$\text{Nap. log. } n = 10^7 \left\{ \text{nat. log.} \left(\frac{10^7}{n} \right) \right\}".$$

On the other hand the Standard Dictionary states, "Napier ian or natural logarithms have for a base 2.718281828." In Vol. VI (1850–1854, page 397) of the *Proceedings* of the Royal Society of London the "Base of Napier's Logarithms" is carried to 205 places of decimals.

Napier's line of thought is expressed in the International Encyclopædia: "Napier observed that if in a circle, with the radius OAo, OA_1 (r = 1) at right angles, the sine SoS_1 parallel to OA_1 moves from O to Ao at intervals forming an arithmetical progression, its value decreases in a geometrical progression. The segment OSo Napier originally called *numerus artificalis*, and later *logarithmus* (ratio numbers)."

For a full presentation of Napier's line of thought and deductions therefrom the reader is referred to the articles by Professor Cajori in the *American Mathematical Monthly*, Vol. 20, 1913; "John Napier and the Invention of Logarithms," Professor Hobson and the "Napier Tercentennary Memorial Volume." See also the valuable articles, "Logarithm" and "Napier" in Encyclopædia Britannica, Eleventh Edition.

Napier published his book, "Mirifici logarithmorum canonis descriptio" in 1614. In it he explained the nature of his logarithms and gave a logarithmic table of the natural sines of a quadrant from minute to minute.

A copy of the 1620 edition of this rare work is owned by the Public Library of New York City. One of the pages is here shown.

The table needs explanation only in the "differentiæ." It will be observed that the figures in this column are the differences between the two columns of "logarithmi." Since

17 mi.	Sinus	Logarithmi	Differentia	Logarithmi	Sinus	
30	3008058	12016225	11542341	473884	9537169	30
31	3009832	12007004	11532202	474802	9536294	29
32	3012606	11997792	11522071	475721	9535418	28
33	3015380	11988589	11511948	476641	9534541	27
34	3018153	11979396	11501835	477561	9533664	26
35	3020926	11970212	11491730	478482	9532786	25
36	3023699	11961037	11481633	479404	9531907	24
37	3026472	11951872	11471545	480327	9531027	23
38	3029244	11942716	11461465	481251	9530146	22
39	3032016	11933569	11451393	482176	9529264	21
40	3034788	11924431	11441329	483102	9528382	20
41	3037559	11915303	11431274	484029	9527499	19
42	3040339	11906184	11421227	484957	9526615	18
43	3043101	11897074	11411188	485886	9525730	17
44	3045872	11887973	11401157	486816	9524844	16
45	3048643	21878881	11391134	487747	9523958	15
46	3051413	11869798	11381119	488679	9523071	14
47	3054183	11860724	11371113	489611	9522183	13
48	3056953	11851659	11361115	490544	9521294	12
49	3059723	11842603	11351125	491478	9520404	11
50	2062492	11833557	11341144	492413	9519514	10
51	3065261	11824520	11331171	493349	951 623	9
52	3068030	11815492	11321206	494286	9517731	8
53	3070798	11806473	11311249	495224	9516838	7
54	3073566	11797463	11301300	496163	9515944	6
55	3076334	11788461	11292358	497103	9515050	5
56	3079102	11779468	11281424	498044	9514155	4
57	3081869	11770484	11271498	488986	9513259	3
58	3084636	11761509	11261580	499929	9512362	2
59	3087403	11752543	11251670	590873	9511464	1
60	3090170	11743586	11241768	501818	9510565	0
						mi. Gr.

$$\frac{\sin x}{\cos x} = \tan x,$$

the log sin x — log cos x = log tau x also log tau x = — log cot x. Therefore, the column headed "differentiæ" gives the logarithmic tangents if taken + and the logarithmic cotangents if taken —.

Two pages thus give the logarithms of the natural sines, cosines, tangents and cotangents for every minute of the degree. It may be observed that the natural sines are given in whole numbers to the radius $10^7 = 10{,}000{,}000$. The decimal point had not been invented. It may also be observed that as the numbers become larger their logarithms become smaller—the "base" being not e but $1/e$.

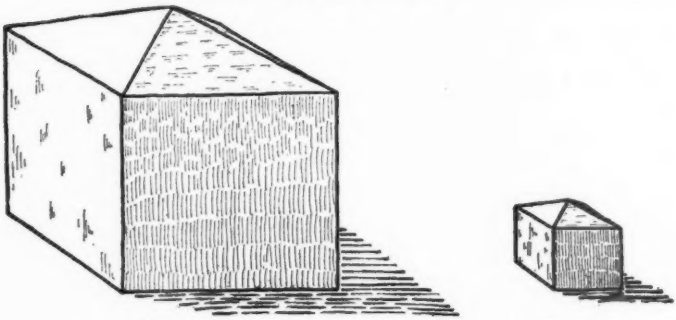
DISCUSSION.

EDITOR, ENGINEERING EDUCATION,

University of Pittsburgh,
Pittsburgh, Pa.

Sir: With reference to the article in your October number by Messrs. Franklin and MacNutt, I wish to suggest a name for the gravitational unit of mass, which I have used successfully for a number of years past. This is the "mydron." The word is derived in the usual manner from the Greek word ὁ μύδρος meaning a lump of metal. This means of getting a scientific term is quite in accord with common usage. The mydron is defined, of course, as a mass of g pounds, where g is

COMPARISON OF MASS UNITS.



Mydron
Cube of iron, 4.9 in. on a side.

Pound
Cube of iron, 1.5 in. on a side.

expressed in feet per second per second. It is just as definite as the pound or the ton, as far as engineers are concerned. To make the concept more real, I use a comparative sketch as shown in the accompanying figure and the students have no difficulty whatever in using the word.

C. J. TILDEN,
Professor of Engineering Mechanics,
Yale University.

CORRELATION BETWEEN ARMY INTELLIGENCE TEST AND COLLEGE RECORDS.

BY E. F. CODDINGTON,

Professor of Mechanics, The Ohio State University.

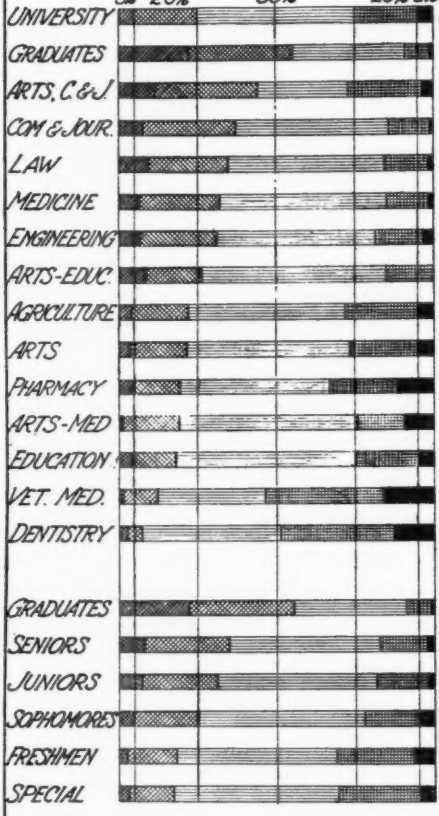
At the beginning of the college year 1919–1920 the authorities of The Ohio State University made an attempt to have all of its students, both men and women, take the Army "Alpha" intelligence test. The total enrollment for the first semester of the year was 6,608 students, of whom 5,904 took the test. The members of the instructional force were also requested to take the same test for their own information.

The test was directed by Dr. George F. Arps, head of the department of psychology, with the assistance of Dr. James W. Bridges. In order to study the results of the test the students were classified by Dr. Arps and Dr. Bridges according to their mental scores as follows:

Class	I	the highest	5% with scores from 178 to 212
	II	the next	20% with scores from 155 to 177
	III	the middle	50% with scores from 115 to 154
	IV	the next	20% with scores from 85 to 114
	V	the largest	5% with scores from 0 to 84

If these students were classified by the Army method, 52 per cent. of them would be placed in class A with the distinction of possessing very superior intelligence. An additional 38 per cent. of them would be placed in class B and characterized as having superior intelligence. By comparing the results of the test upon our students with that made upon the men in the service, we find that 90 per cent. of our students are of equal intelligence to the best 25 per cent. of the rank and file of the men of the United States who served in the late war. Should we not conclude that 90 per cent. of engi-

· INTELLIGENCE · DISTRIBUTION ·



CLASS POINTS

I = 178-212 HIGHEST 5% OF UNIVERSITY STUDENTS
II = 155-177 NEXT 20% " " "
III = 115-154 MIDDLE 50% " " "
IV = 85-114 NEXT 20% " " "
V = 0-85 LOWEST 5% " " "

neering students are selected from the best 25 per cent. of our American youth?

614 of these students are first-year men enrolled in the College of Engineering who completed their first semester's work more or less sucessfully. This paper is an attempt to correlate the results of the mental test of these 614 men with their scholastic records during this semester.

Applying the classification adopted by Dr. Arps, we find these 614 students distributed as follows:

	I.	II.	III.	IV.	V.	
Number.....	24	133	331	96	30	614
Percentage...	3.9	21.6	53.9	15.6	4.9	99.9

This distribution, which is very close to that of the entire student body, when compared with that for the first-year class of the entire university shows that the first-year engineers made the higher average score. Though this does not demonstrate that the College of Engineering draws the more capable students, it is in accord with results found in the Army, where the engineering units stood the highest compared with other professional units.

At The Ohio State University the following initials have been adopted to indicate the quality of work done:

M signifies work of exceptional merit.
G signifies excellent work.
A signifies average work.
P signifies passing work (the lowest mark carrying credit).
C signifies condition work (re-examination necessary for credit).
F signifies failing work (must be repeated in class).

The quality of the work of the different groups is shown in Table I. This table was constructed by taking the total number of credit hours with which each group was charged and computing the respective percentages of these totals marked by the instructors as "M," "G," "A," etc.

TABLE I

	No.	M %.	G %.	A %.	P %.	C %.	F %.	
I	24	20.1	34.7	36.2	7.3	0.5	1.3	100.1
II	133	10.8	19.3	39.6	21.3	3.0	6.0	100
III	331	5.3	14.6	36.4	26.0	4.9	12.9	100.1
IV	96	2.5	6.6	32.1	34.0	5.4	19.0	100
V	30	0.0	5.5	22.5	37.7	9.5	24.8	99.9
Total	614	6.4	14.8	35.8	26.0	4.6	12.4	100

This table shows clearly that in the aggregate there is an unmistakable decline in the quality of the work of the students in passing from a group of high average to one of a lower average. It does not show, however, the variation of the work of the individual in any given group. It gives rather a bird's-eye view of the quality of work done by the student when grouped according to mental scores.

The following table subdivides each group into three groups according to the quality of the work done; (1) Those who made clear records; (2) those who did not make clear records but received credit for two thirds of the work carried; (3) those who failed to pass two thirds of their work and consequently were automatically placed on probation by faculty rule.

TABLE II

	No.	Record Clear.		Passed ⅔ or More.		Passed Less than ⅔.	
		No.		No.		No.	
I	24	22	91.7	2	8.3	0	0.0
II	133	95	71.4	32	24.0	6	4.5
III	331	179	54.1	89	26.9	63	19.0
IV	96	42	43.8	30	31.2	24	25.0
V	30	7	23.3	10	33.3	13	43.3
Total	614	345	56.2	163	26.5	106	17.3

Here again a majority of the good students is found in the groups of high score. It is also evident that, of the small number found in Group V, there are very few who will be at

all successful in completing the requirements for a degree. Of the thirty men found in Group V only seven made clear records and a majority of the credits obtained by them was of grade "P." Two of these seven men are foreigners. This fact may account for their low scores.

These facts would seem to indicate that boys who make a score of 85, or those composing Group V, are not of proper mental caliber to be successful with university work. Since, however, so few of those who apply for admission make such low scores, and since occasionally one is found who is successful, it does not seem advisable to exclude anyone by the Army test.

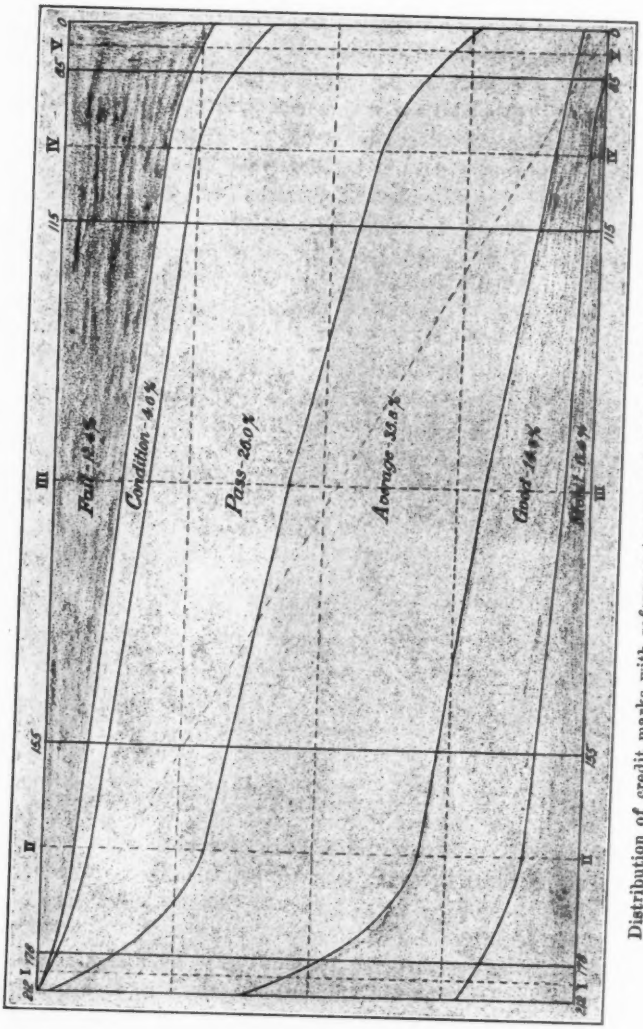
The above tables direct attention to the quality of the work of the different groups without taking into consideration the unequal size of the groups. Both of Groups I and V are too small to receive much consideration. In order to show how the different grades of work were distributed among the various groups Table III has been compiled.

TABLE III

	I.	II.	III.	IV.	V.	Total.
Number	24	133	331	96	30	614
Percentage ..	3.9	21.6	53.9	15.6	4.9	99.9
M.....	12.5	37.5	44.8	5.8	0.0	100.1
G.....	9.3	29.0	53.3	6.7	1.7	100
A.....	4.0	24.4	55.0	13.6	3.0	100
P.....	1.1	18.0	54.1	19.8	6.9	99.9
C.....	0.4	14.2	57.9	17.7	9.8	100
F.....	0.2	10.7	56.0	23.6	9.5	100

The data given in these tables have been plotted on the accompanying chart in order to show graphically the dependence of scholarship upon the ability to obtain a high score in the Army Intelligence Test.

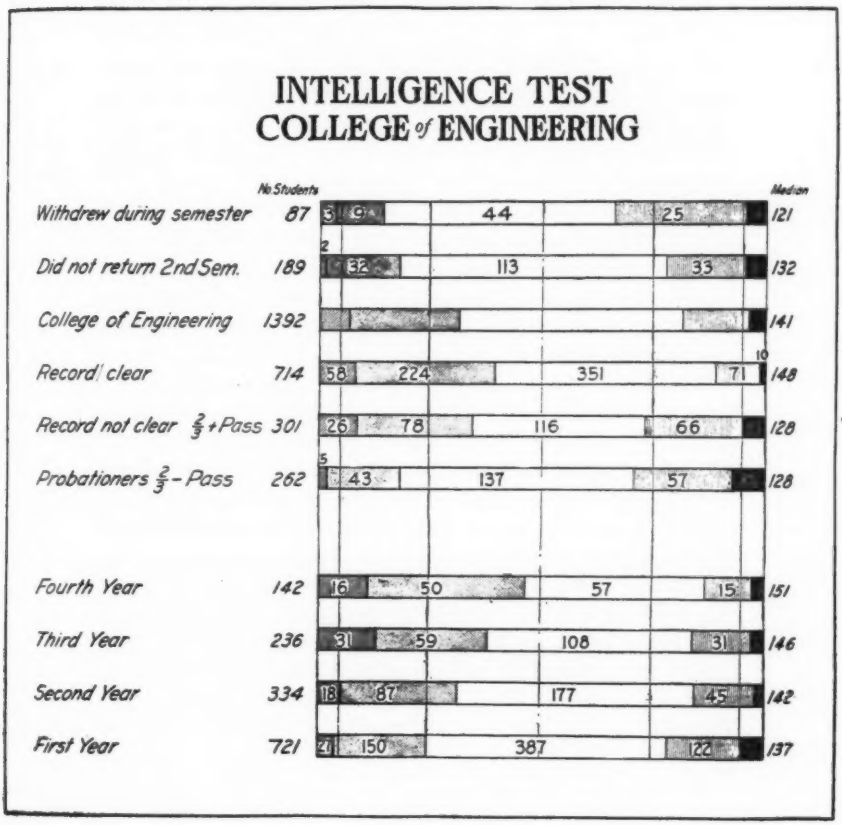
The chart was constructed by plotting to scale as abscissa, the percentages of the 614 students contained in each group beginning on the left with Group I. At the middle of each of



Distribution of credit marks with reference to score of Alpha Test of 614 first-year students.

these five divisions was plotted to scale as ordinates, the percentages of merit work, good work, etc., done by the representative groups beginning at the bottom with merit work. Curves were then traced through the corresponding division points of the several ordinates.

It is evident that if the area of the rectangle is taken to represent the total amount of work done by all of the 614 students, the curves divide this area into parts which are


INTELLIGENCE TEST
COLLEGE of ENGINEERING
No Students
Median
Withdrew during semester 87 3 9 44 25 121
Did not return 2nd Sem. 189 2 32 113 33 132
College of Engineering 1392 141
Record clear 714 58 224 351 71 10 148
Record not clear 2/3+Pass 301 26 78 116 66 128
Probationers 2/3-Pass 262 5 43 137 57 128
Fourth Year 142 16 50 57 15 151
Third Year 236 31 59 108 31 146
Second Year 334 18 87 177 45 142
First Year 721 21 150 387 122 137

proportional to the percentages of merit work, good work, etc., done by these students. These parts are subdivided by the ordinates bounding the groups into areas which are proportionate to the relative amounts of each grade of work done by the respective groups. The slope of the curves, going from right to left, indicates the rate of improvement in scholarship in ascending the scale of mental scores.

Three facts indicated by this chart are interesting if not surprising. First, the improvement of the grade of work with reference to mental scores may be quite accurately represented by straight lines beginning with the middle of Group IV and ending with the middle of Group II. This means that for 70 per cent. of these students with mental scores ranging from 100 to 166 the grade of scholarship improves uniformly with increasing mental scores. Second, the rate of increase of scholarship for this large percentage of our students is not at all pronounced. Third, the amount of work done by this large group which is barely passing or of lower quality is altogether too large. It is approximately 44 per cent. of the work taken by them.

This raises the question as to who is responsible for the poor showing made by so large a percentage of our first-year students at the end of their first semester's work. I do not believe lack of mental ability can be used to account for it. If this were true, the rate of increase of good work with respect to increasing mental scores would be more pronounced. No doubt poor preparation, lack of interest, lack of engineering ability, and new and unfamiliar conditions is the cause of a large part of this poor work. The question might be raised as to whether poor teaching is not responsible for a considerable part of it. Also might not something be done to alleviate the adverse conditions encountered by students during their first year?

EDITORIAL.

HIGHWAY TRANSPORT.

BY ROY D. CHAPIN,

Vice-President, National Automobile Chamber of Commerce.

During the life time of the college student of today, virtually 9,000,000 fast-moving, time-saving motor vehicles have been fabricated in American manufacturing plants and thrust into the active service of hauling freight and passenger traffic over the 2,500,000 miles of highway in the United States.

Before the advent of this modern unit of highway transport, the average vehicle on the road travelled about ten miles a day. Economic development was limited by our waterways and railroads, the consolidated school was an impossibility and isolation was the rule rather than the exception for those who have made their living from the soil.

A mere infant as yet, its possibilities for public service only just beginning to be appreciated, the motor vehicle has already been the genesis of a far-reaching movement in mass economics which is destined to disturb all of our preconceived theories of city and country planning and to bring about a new and more intense nationalism as a result of flexibility of communication which it permits.

The solitary automobile chugging its way over trackless wastes from outlying farm to community center; the heavily loaded motor truck plying its course from fields of wheat to distant railroad spurs, may not in themselves seem to present any great problem, but multiplied by 9,000,000 either becomes at once a national question which presents problems reaching into the very heart of our whole sociological and economic structure, and which can be solved only by the intensive effort of the best minds of our educational world. For, fundamentally, this question in transportation, like all other affairs

which press close upon national life, is a matter for research and study which can only be met by educators and then only as it is attacked in each of its aspects.

At its very core, the question which presents itself, is resolved into the need for a vast personnel of skilled men. It is not enough that we should seek to give these men a basis of education in the mere physical questions of highway construcion and maintenance. Far more important it is, that they should first understand the underlying purposes for which it is proposed to construct the road. Hundreds of millions of dollars have already been voted for highway construction. Billions will be granted by a public keenly alive to the necessities of economic road transport.

It is the task of the educator to see to it that these men will be able to analyze the economics underlying road use, to locate their highways so that they will not only serve the purposes of a traffic far beyond past conception, but so they will serve that traffic at the lowest cost and with the widest possible margin of insurance to the public. Intricate problems of finance will face them. Economic studies of tonnage possibilties and trends will need to be analyzed. Equitable regulation of the traffic will confront them. Ways and means of keeping the highway open the year around and of keeping it at maximum efficiency will be at issue. The construction of the vehicle itself, its distribution and finally, its economic use are among the steps to be considered. Safety must be assured, cities, towns, and rural sections alike must be replanned to provide a maximum of service and again a minimum of cost.

No one today can tell how far highway transport will go, how vital the influence it will have upon the comity of nations as well as of states.

But the lessons of the past as told in the sum total of the experience of Dr. Jones with his coupe and Henry Smith, the farmer, with his truck, and Jim Hughes, the salesman with his roadster, and countless others, furnish the basis for a new curriculum. The rest remains with the educator.

COLLEGE NOTES.

University of Michigan.—Five Fellowships have been awarded to the following highway engineers and highway transport specialists by the board of regents of the University of Michigan. These men are in residence during the winter period from December to March, inclusive, and are candidates for the degree of Master of Science in Highway Engineering or Highway Transport. The titles of their investigations are included in the statements covering their educational and engineering training.

Roy D. Chapin Fellow in Highway Transport: Hershel C. Smith, Oklahoma City, Oklahoma; A.B., 1913, University of Michigan; B.C.E., 1915, University of Michigan. Mr. Smith has been continuously engaged in highway work since 1915, having occupied the position of deputy chief engineer of the Oklahoma State Highway Department, and has been practicing as a Consulting Engineer specializing in highway work. Investigation: Highway Transport Economics.

Roy D. Chapin Fellow in Highway Engineering: Richard R. Fauver, Lorain, Ohio, A.B., 1917, Oberlin College. Graduate student in highway engineering, University of Michigan, December, 1919, to March, 1920. Since 1917, engaged in highway construction work with the Ohio Engineering Company. Investigation: Economic Aggregates for Cement Concrete Pavements and Structures.

Detroit Edison Fellow in Highway Engineering: E. R. Olbrich, assistant professor of highway engineering, Oklahoma Agricultural and Mechanical College. C.E., 1915, Pennsylvania State College. From June, 1915, to November, 1920, Professor Olbrich was engaged in highway engineering work with the Bureau of Highways of Philadelphia and the Barrett Manufacturing Company, and in railroad work with the

Southern Railway Company. Investigation: Dust Preventatives and Surfaces Preservatives for Gravel Roads.

Detroit Edison Fellow in Highway Engineering: Chia T. Yeh. B.Sc. in C.E., 1916, Government Institute of Technology, Shanghai, China. M.C.E., June, 1920. Cornell University. In 1917, Mr. Yeh was appointed by the Government of Kwangtung Province to make a survey of thirty miles of military road at Waichow. During 1917, he was also connected with the Maintenance of Way Department of the Kwangtung Samshiu Railroad. In 1918, he was sent to the United States by the Chinese Government to study American practice in highway engineering and highway transport in order to make use of this knowledge in connection with the future development of transportation and highways in China. Investigation: Binding Value of Michigan Gravels.

National Steel Fabric Company Fellowship in Highway Engineering: Harold Tuttle Corson; B.S. in C.E., June, 1918, University of Michigan; 1918–1919, teaching assistant in charge of sanitary experiment station and 1919–1920, graduate student in civil engineering and instructor in surveying, University of Michigan; June, 1920, to September, 1920. Instructor in surveying, Camp Davis; September, 1920, to date, engineer in appraisal office, Ann Arbor. Investigation: Design of Cement Concrete Pavements and Foundations as Structures.

Each graduate short period course is given in a period of two weeks and consists of thirty lecture hours in afternoon periods, while the mornings are devoted to library research work in the Davis Library of Highway Engineering and Highway Transport, which is the most complete collection of literature on these subjects in existence. In connection with some courses, the fully equipped highway engineering and automotive laboratories are used for research work. Any man over twenty-one years of age is admitted to these courses, while men holding Bachelor's degrees may become candidates for the Master of Science degree. A man may take one course or a group of courses depending on the duration of his leave of

absence from the department or company with which he is connected.

In addition to the members of the faculty of the University of Michigan, between ten and fifteen non-resident lecturers, experts in highway transport, will deliver lectures in the several courses.

The men who registered during December, include engineers, contractors, and highway transport specialists varying in age from twenty-four to forty-five years and who have come from the States of Washington, Texas, Oklahoma, Mississippi, Wisconsin, Michigan, Ohio, West Virginia, Pennsylvania, New York, New Jersey and the Provinces of Quebec and Saskatche wan, and two engineers sent by the Chinese Government to specialize in highway transport.

North Carolina State College of A. & E.—College has opened this year with a heavier registration than ever before in spite of our increase in entrance requirements. Up to this year we have not felt justified in requiring 14 units, as the county high schools were not able to prepare their students that we must admit. We are glad, however, to find that the change has not cut down our registration. We probably would have had a much heavier enrollment had we not increased our requirements.

BOOK REVIEWS.

American Rural Highways. By T. R. Agg. 1st edition. McGraw-Hill. 138 pages, $5\frac{1}{2} \times 8\frac{1}{2}$.

A textbook intended for agricultural engineers, students in agriculture, and for short courses and extension courses. It is adapted primarily for students who do not receive training along the lines of the usual course in Highway or Civil Engineering. The methods of design and construction of earth roads, sand-clay and gravel roads, broken stone roads, concrete roads, brick roads, and bituminous surfaced roads are taken up sufficiently to show the relative desirability and distinguishing characteristics of each of these types. Sixty-two pages are also devoted to the social side of highway improvement, methods of highway administration, and problems in design common to all types of road surfaces. The book admirably fills the niche for which it was written, a sort of layman's treatise on the art of road making. It could profitably be read by anyone interested in improved highways.

J. M.

Engineering for Land Drainage. By Charles Gleason Elliott, C.E. John Wiley & Sons. 3d edition. 363 pages. $5 \times 7\frac{1}{2}$.

A general treatise on drainage engineering in this country at the present time; adapted to the use of both the professional engineer and the student. It includes the historical development of the drainage of natural swamps and overflow lands and states in a brief but comprehensive way the principles involved in the design of drainage structures. The various systems of locating underdrains and the calculation of the flow therefrom is discussed in a non-technical, yet complete fashion, the text being supplemented by various useful tables and illustrated by actual examples. Field methods designed for making the preliminary surveys and for use in construc-

tion contain the essentials without too much useless detail. The discussion of the flow in open channels and the run off from large areas is rendered complete by the insertion of numerous records and helpful charts and diagrams. The author renders the work complete by chapters on the reclamation of tidal lands, levee drainage systems, drainage of irrigated lands, drainage of peat and muck land, and methods of preparing estimates and financing of drainage improvements in drainage districts. The outstanding feature of the book is the simplicity with which it is written and at the same time the comprehensive nature of the information contained therein.

L. McI.

Fuel Oil in Industry. By STEPHEN O. ANDROS, A.B., E.M. Shaw Publishing Company. 1st edition. 244 pages. 6×9.

A description of the methods of using fuel oil and the appliances and accessories for handling and burning it. The methods of testing and the various test apparatus are fully described and illustrated. The chapter on comparison of coal and fuel oil furnishes comprehensive data on which to base decisions regarding the relative merits of these fuels for any particular case. Methods of storing fuel oil are fully described and typical laws regulating storage are inserted. The types of oil burners and their adaptation to the various kinds of boilers are fully illustrated. Chapters are devoted to the use of fuel oil in steam navigation, locomotives, the manufacture of iron and steel, production of electricity, the sugar and glass industries, and in the heating of buildings. The book covers the ground indicated by its title in a thoroughly complete manner, although a more careful proofreading would eliminate several typographical errors.

L. W. M.

OBITUARY.

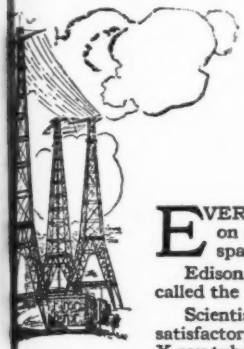
O. A. Randolph, associate professor of physics at the University of Colorado, died April 11, 1920. He was born in Missouri and graduated from the Central High School, Kansas City, in 1906. He received the degree of B.S from the Missouri School of Mines and Metallurgy in 1911, and the Ph.D. in Physics in 1916 at the University of Illinois.

Professor Randolph was an instructor in physics at the University of Illinois from 1911 to 1916. From 1916 to 1918 he was instructor in physics at the University of Colorado, 1918 to 1919, assistant professor, and associate professor from 1919.

Professor Randolph was a member of Tau Beta Pi, Sigma Xi, the American Physical Society, the American Chemical Society and the Society for the Promotion of Engineering Education.

"Professor Randolph was one of the most promising young men on our faculty, hard working and efficient, and universally loved by the students. He was very fond of mountain climbing and with another member of our department of physics had made a trip to the top of the Continental Divide to take some winter photographs of a particularly stormy and (at that season of the year) dangerous place known as the Hell Hole. He and his companion travelled in skis against the advice of friends that they take snow shoes or not go at all. The damp snow of the night of April 10 made skis useless and without them they could make no progress in the snow five feet or more deep.

"The result was that Dr. Randolph gave out, was wrapped up by his companion who, almost exhausted himself, went for help. The latter was found lost and wandering around by a trapper who made all the speed he could to Dr. Randolph but found him dead." (Abstracted from *Chemical Abstracts.*)



How is a Wireless Message Received?

EVERY incandescent lamp has a filament. Mount a metal plate on a wire in the lamp near the filament. A current leaps the space between the filament and the plate when the filament glows.

Edison first observed this phenomenon in 1883. Hence it was called the "Edison effect."

Scientists long studied the "effect" but they could not explain it satisfactorily. Now, after years of experimenting with Crookes tubes, X-ray tubes and radium, it is known that the current that leaps across is a stream of "electrons"— exceedingly minute particles negatively charged with electricity.

These electrons play an important part in wireless communication. When a wire grid is interposed between the filament and the plate and charged positively, the plate is aided in drawing electrons across; but when the grid is charged negatively it drives back the electrons. A very small charge applied to the grid, as small as that received from a feeble wireless wave, is enough to vary the electron stream.

So the grid in the tube enables a faint wireless impulse to control the very much greater amount of energy in the flow of electrons, and so radio signals too weak to be perceived by other means become perceptible by the effects that they produce. Just as the movement of a throttle controls a great locomotive in motion, so a wireless wave, by means of the grid, affects the powerful electron stream.

All this followed from studying the mysterious "Edison effect"— a purely scientific discovery.

No one can foresee what results will follow from research in pure science. Sooner or later the world must benefit practically from the discovery of new facts.

For this reason the Research Laboratories of the General Electric Company are concerned as much with investigations in pure science as they are with the improvement of industrial processes and products. They, too, have studied the "Edison effect" scientifically. The result has been a new form of electron tube, known as the "pliotron", a type of X-ray tube free from the vagaries of the old tube; and the "kenetron", which is called by electrical engineers a "rectifier" because it has the property of changing an alternating into a direct current.

All these improvements followed because the Research Laboratories try to discover the "how" of things. Pure science always justifies itself.

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"I know what helped me to turn the trick. Back at college I put in some hard licks on the football field, and that training to think fast in a pinch and to keep plugging with the odds against me certainly stood by me when I graduated from football togs to overalls at the electrical works.

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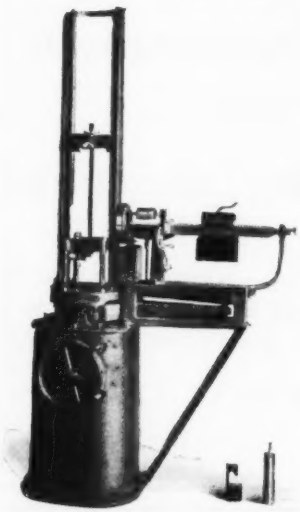

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